# A Preliminary Beam Permit System for the Neutrino-Muon Beamline

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**Abstract:** This document describes a permit system for the Neutrino-Muon beamline that can inhibit beam to the SeaQuest experiment without affecting the MTest and MCenter experiments. The system allows beam to SeaQuest only if the target is finished moving, the last two quadrupoles in the line are up to current, and the experiment's first analyzing magnet is at an acceptable current. Controlled by the permit system, the dipole string S:V100 either sends beam to the SeaQuest experiment or the Switchyard dump. This system was developed as an intermediate step while investigating the implementation of a C200/201/204 permit system as used by the accelerators.

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**References and links**

1. Electronic Log Book, "Entry 48047," https://www-bd.fnal.gov/Elog/?entryIDs=48047
2. AD Controls CAMAC Modules, "SeaQuest E906 Ramp Permit", J. Gomilar et. al., http://www-bd.fnal.gov/controls/camac_modules/schematics/E906_Ramp_Permit.pdf

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## 1. System Overview

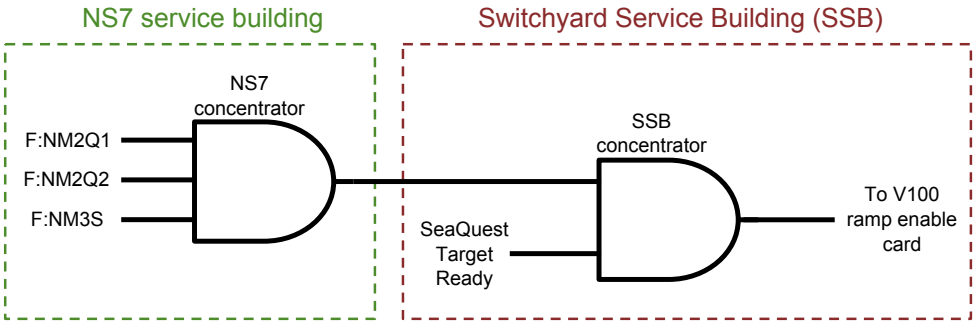


Fig. 1. Logical overview of permit system

Development of this permit system was motivated by a high-loss event on March 31, 2015: the power supply for the last quadrupole in the Neutrino-Muon beamline, F:NM2Q2, failed to ramp to full current before beam arrived[1]. This caused a dramatic increase in the beam size, leading to excessive beam loss. The permit system project was motivated by the desire to protect accelerator and experiment detector equipment from excessive beam loss without interrupting beam to experiments in the Meson line.

The system consists of two CAMAC modules to concatenate permit signals, and a third CAMAC module to enable the power supply ramp for S:V100, which is a critical device for the Neutrino-Muon beamline. A logical overview of the system is given in Figure 1. The permit signal between the NS7 and SSB service buildings is a 15 mA current, as is the target-ready signal from the SeaQuest experiment. The SSB concentrator card outputs a 5V TTL permit signal to the V100 ramp enable card.

Permit currents to SSB from SeaQuest and NS7 are transported by a surplus twisted-pair cable courtesy of the AD ESHQ Interlocks group. The SeaQuest target-ready signal is generated by the experiment's target PLC.

Lack of a V100 ramp permit causes the beam to drift through to the Switchyard dump without entering the Neutrino-Muon beamline. This is communicated to the Main Control Room via the digital status of F:NMPRMT, illustrated in Figure 2. Lack of a beam permit will show "Beam Permitted....INHIBIT" and "Missed Gate.....Yes" in the digital status, indicating that no permit was provided by the SSB card and that S:V100 did not ramp. The digital alarm for F:NMPRMT updates on the TCLK $3D event, and will enunciate in the alarm screen if there is no beam permit when the slow-spill cycle begins.

Currently, the permit system does not remotely communicate which input is responsible for an inhibited permit; that information can only be found on the front face of each card. For now, Operators in the Main Control Room can use the alarm screen to see if any of the power supplies related to the permit were not up to current. Future plans, mentioned at the end of this document, include the ability to remotely communicate through ACNET which input channel inhibited the beam permit.

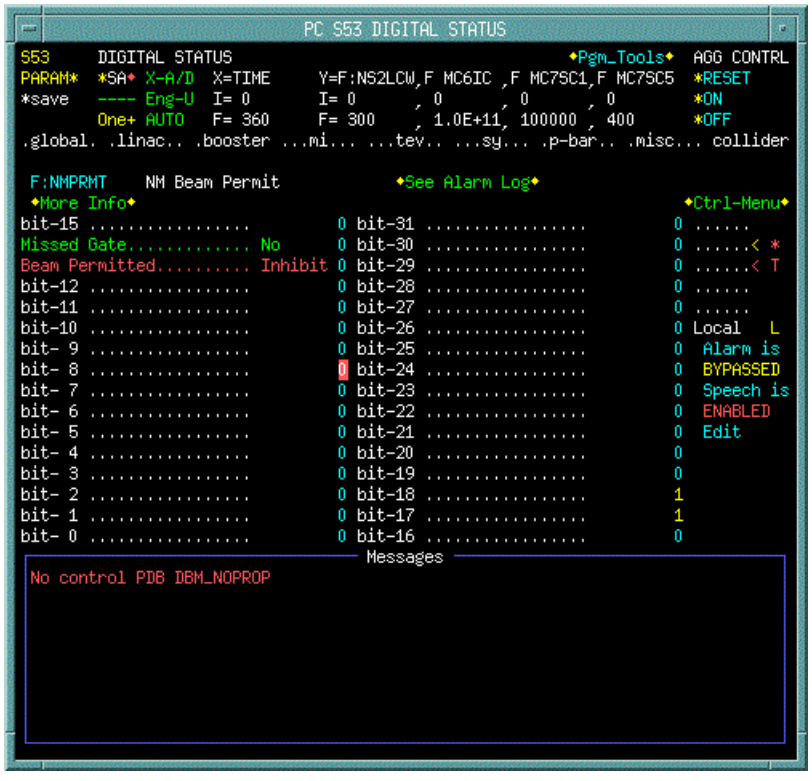


Fig. 2. Digital status for F:NMPRMT device

## 2. Module Descriptions

This section describes the permit system's constituent modules in greater detail. The NS7 and SSB concentrator modules were developed by AD External Beams, and the V100 ramp enable module by the AD Controls group.

### *2.1. NS7 Concentrator*

Shown in Figure 5, the permit concentrator card at the NS7 service building monitors the last two quadrupoles in the NM beamline (F:NM2Q1 and F:NM2Q2) and the experiment's first analyzing magnet (F:NM3S). If all three power supplies are providing enough current, a 15 mA permit current is sent to SSB.

A Texas Instruments LM311 differential comparator monitors each power supply output current; the permit system uses the same voltage readback from the power supply that goes to the ACNET MADC for remote reading. This voltage is proportional to the power supply current, and the proportionality relationship is stored in the ACNET device database. Thus the voltage on the LM311 reference pin can be set using a potentiometer to represent any desired power supply current. If the actual power supply current is not higher than the reference, the LM311 outputs a TTL low signal (i.e. 0 V), and the beam permit is not sent to SSB.

The TTL output of each comparator is summed with a 74LS21 AND gate. The output of the AND gate is inverted twice using a 74128 chip, solely to source more current to the output stage of the card than the 74LS21 could provide alone. Finally, the output of the 74128 gates an NPN transistor that sends 15 mA to SSB if all three monitored power supplies are up to current.

Shown in Figure 3, the front panel of the NS7 card consists of input and permit status LEDs, lemo connector test points to measure the reference for each input channel, trimpots to adjust each reference, and bypass switches for each channel. Knowledge of the aforementioned database equation to convert power supply monitor voltage to output current is necessary to properly set the comparator references, but this is easily provided by the ACNET D80 application.

Three red LEDs show the status of each input; a red light means the monitored supply is up to current, and no light means it is not and thus the permit is not sent. A green permit LED shows that the permit signal is being sent to SSB when lit. Any of the input channels can be bypassed by flipping the corresponding toggle switch *down*, which ties the input of that channel's LM311 to the +5V rail of the card (i.e. TTL high).

Input and output signals for the NS7 card are transmitted by a Viking connector attached to the CAMAC module and a lemo patch panel in the back of the rack. This allows for easy testing and swapping of inputs if necessary, as well as easy testing of the output before it connects to the cable running to SSB.

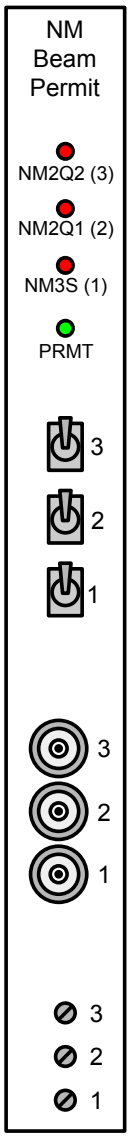


Fig. 3. NS7 card face.

### *2.2. SSB Concentrator*

The SSB concentrator card, shown in Figure 6, converts the 15 mA signals for SeaQuest target ready and NS7 permit into TTL active-high signals, and concatenates them with a 74LS21 AND gate. As with the NS7 card, the SSB card uses a 74128 to twice invert the TTL output of the AND gate; again, this is to increase the amount of current able to be sourced from the output stage of the card. The output signal from the SSB concentrator is an active-high TTL voltage.

The front card face, pictured in Figure 4, is similar but simplified as compared to the NS7 card. The SSB card has a status LED for each input channel and an LED for the permit status; as with the NS7 card, a lit LED means a "good" input or permit status. Each input channel can also be bypassed by flipping the associated toggle switch *down*, which ties that channel to the +5V rail (i.e. TTL high).

### *2.3. V100 Ramp Enable Module*

Developed by the AD Controls group, this module provides the ramp permit for the S:V100 power supply[2]. The card can accept either a TTL active-high voltage or a current as the input. Before the NS7 and SSB concentrator cards were added, the SeaQuest target-ready 15 mA signal was connected directly to the input of the V100 Ramp Enable card. Now, however, that input is connected to a lemo patch panel in the back rack; it is now possible to connect either the SeaQuest target-ready signal *or* the output of the SSB concentrator to the V100 card. For example, if anything goes wrong with the SSB or NS7 cards, one can disconnect the SeaQuest target-ready cable from the input of the SSB card and connect it directly to the V100 card via the patch panel.

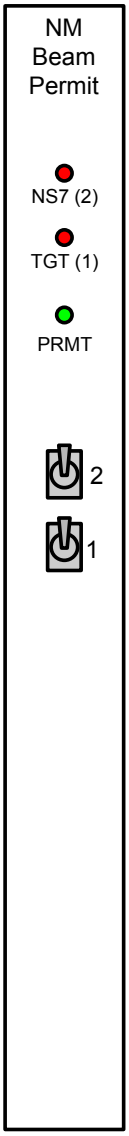


Fig. 4. SSB card face.

## 3. Potential Improvements

Two major improvements are possible for this permit system, both with the goal of improving scope and remote communication of the permit status. The near-term improvement involves the addition of a CAMAC module for digital status expansion, while the longer-term improvement plan is a complete replacement of the entire system.

### *3.1. Digital Status Expansion*

To improve the ability to remotely determine which input channel is responsible in the event of a permit inhibit, a CAMAC c185 module may be implemented at both NS7 and SSB. The c185 is a general digital input monitoring card that can populate the digital status of an ACNET device based on digital signals in the service building. It is relatively simple to tie the TTL signal for each input channel at SSB and NS7 to a digital input of a c185 card. For example, the NS7 c185 could populate the device F:NS7PT with digital status bits for the NM3S, NM2Q1, and NM2Q2 supplies; if a permit inhibit situation occurs, operators could check which c85-generated digital device was in alarm to narrow down the cause of the issue. This upgrade should be relatively straightforward to implement.

### *3.2. C200 Permit System*

Future work will look into the feasibility of using a CAMAC c200 permit system to replace the SSB and NS7 modules described in this paper. The c200/201/204 suite of cards provide fast and accurate beam permit information with a robust remote interface and communication system through ACNET. Permit systems for all Accelerator Division accelerators and several experimental beamlines use the c200 card system, and both the AD Controls and Operations groups are very familiar with them.

Feasibility of the c200 system in the Neutrino-Muon beamline will rely upon the ability of the in-place cable infrastructure to transmit the 5 MHz clock signal used by the cards. It remains to be shown whether amplifiers or repeaters are necessary to carry the permit signal for the c200 system throughout the beamline, but early indications are promising. Investigation of this upgrade will be illustrated in a later document. The system described in this paper was designed with the possible limitations of twisted-pair cable in mind: simple DC permit signals have no problem travelling over the cables already installed, so the described system is a first-pass implementation. Use of a c200 system would greatly improve the flexibility and user-friendliness of the Neutrino-Muon permit.

## 4. Conclusion

A simple beam permit system was developed for the Neutrino-Muon beamline that can inhibit beam to the SeaQuest experiment in the event that their target is not ready or a sample of beamline elements are not in the correct configuration. This was motivated a beam-loss event that illustrated the beamline's vulnerability to single-quadrupole failure. This system is a first-pass implementation with many options for improvement in both the scope and usability, and future work will probe the feasibility of the aforementioned upgrades.

## 5. Acknowledgements

I'd like to thank Rupe Crouch and Joe Gomilar of AD Controls, the AD ESHQ Interlocks group, Mike Geelhoed of the AD ESHQ Radiation Safety group, and Todd Johnson and Paul Allcorn of AD Operations for their invaluable help with this project.

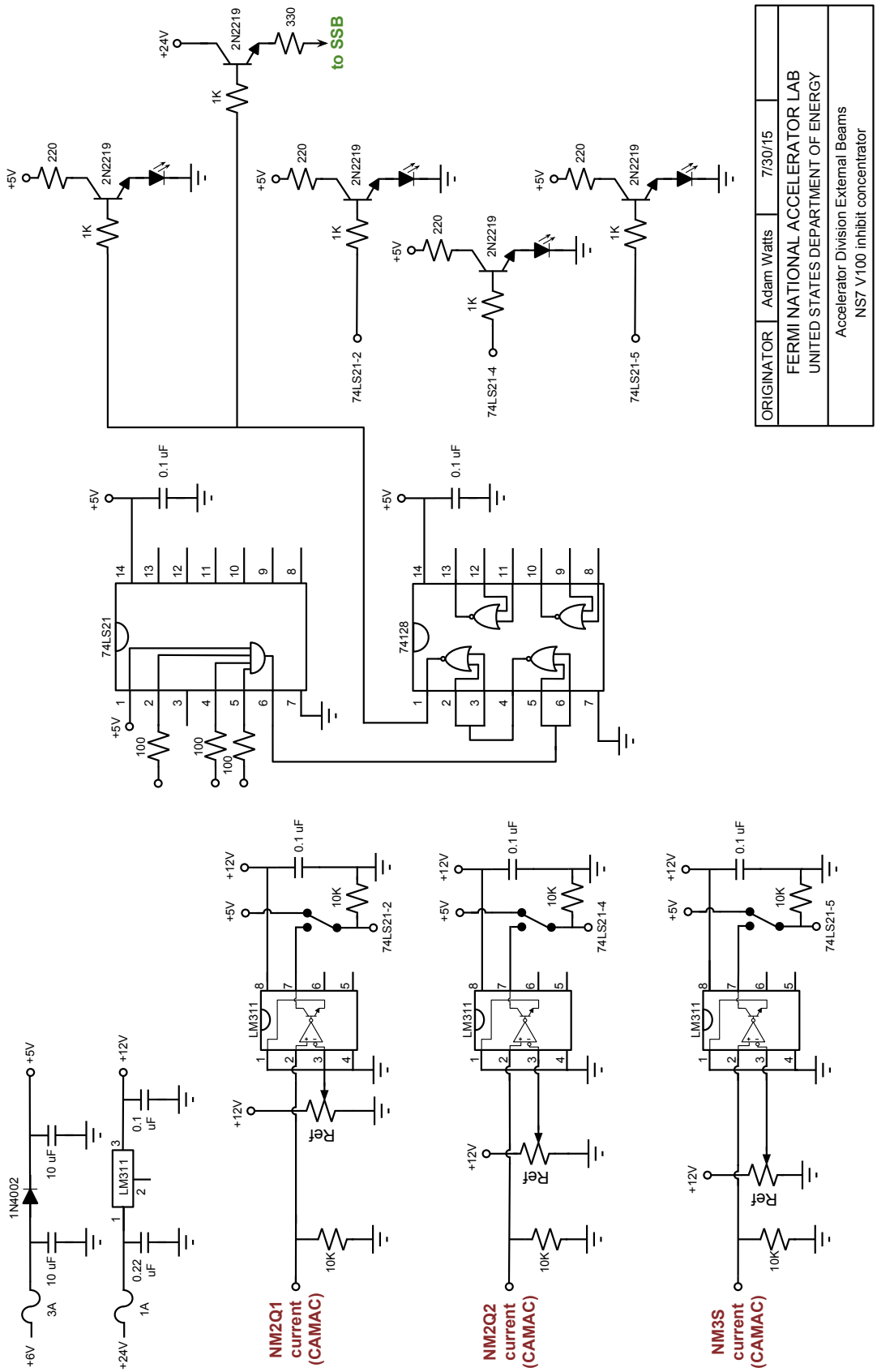


Fig. 5. NS7 concentrator module schematic

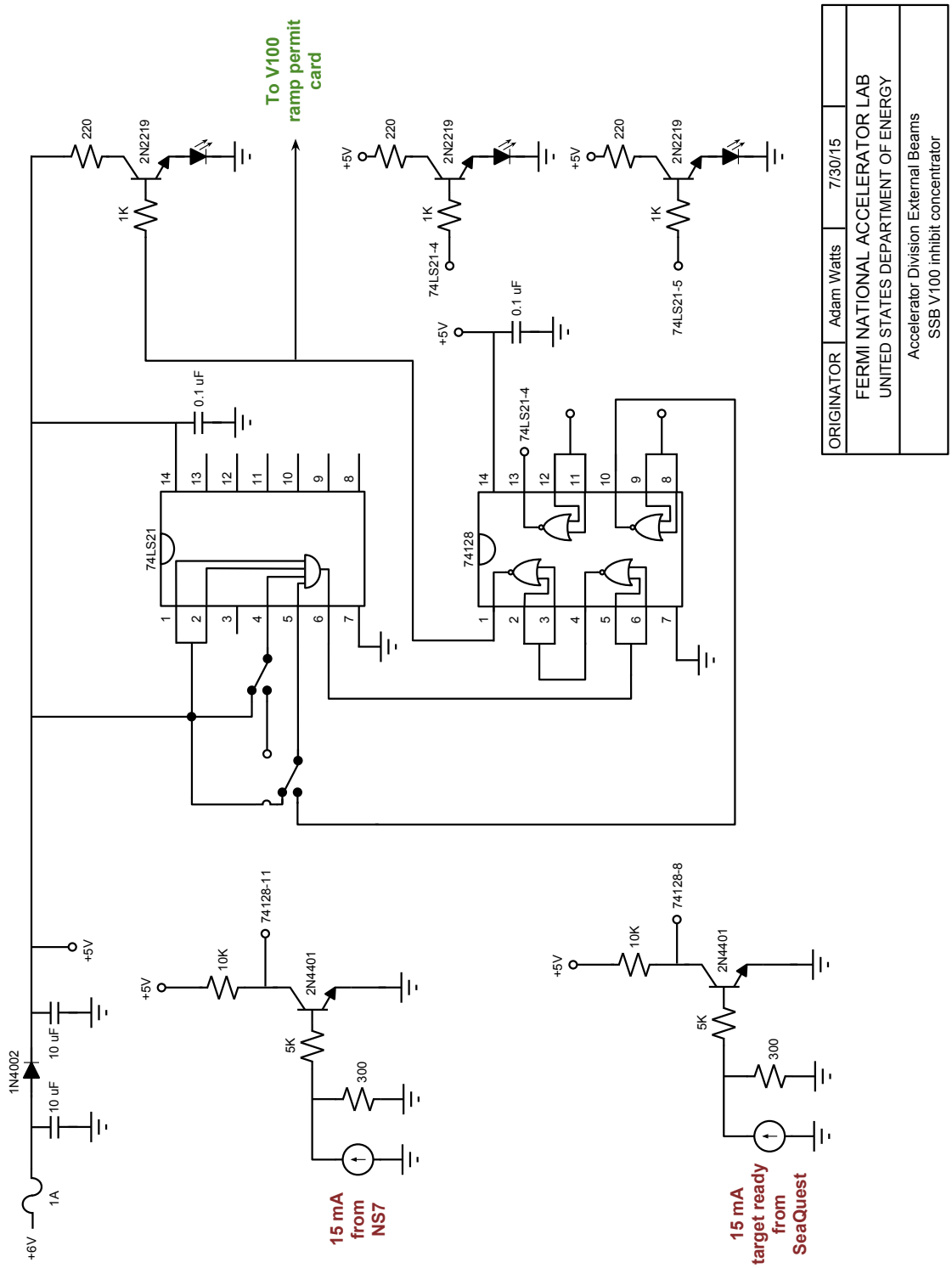


Fig. 6. SSB concentrator module schematic